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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

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First Named Inventor or Application Identifier

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APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
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1. [X] Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. [X] Specification *[Total Pages -15]*
(preferred arrangement set forth below)
- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings *(if filed)*
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. [X] Drawing(s) *(35 USC 113)* *[Total sheets -5]*
4. [X] Oath or Declaration *[Total Pages - 5]*
a.1. [] Newly executed (original or copy)
a.2. [X] Unexecuted
b. [] Copy from a prior application (37 CFR 1.63(d))
(for continuation/divisional with Box 17 completed)
[Note Box 5 below]
i. [] DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. [] Incorporation By Reference
(usable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. Microfiche Computer Program *(Appendix)*

7. []Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. [] Computer Readable Copy
b. [] Paper Copy (identical to computer copy)
c. [] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [] Assignment Papers (cover sheet & document(s))
9. [] 37 CFR 3.73(b) Statement [] Power of Attorney
(when there is an assignee)
10. [] English Translation Document *(if applicable)*
11. [] Information Disclosure Statement (IDS)/PTO-1449
[] Copies of IDS Citations
12. [] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
14. [] Small Entity Statement(s)
[] Statement filed in prior application, Status still proper and desired
15. [] Certified Copy of Priority Document(s)
(if foreign priority is claimed)
16. [] Other

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information:*
[] Continuation [] Divisional [] Continuation-in-part (CIP) of prior Application No.

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May 23, 2000

METHOD FOR INSPECTING PRINTING STATE AND SUBSTRATE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of methods for inspecting the printing state of materials printed on substrates, and substrates to be printed

2. Description of the Prior Art

In the manufacturing process of circuit substrates (hereinafter referred to as "substrates") on which electronic components are mounted, the mounting state is inspected to secure the reliability of each product. Normally, an appearance inspection is implemented using a camera for examining the soldering state of electronic components mounted on a substrate. CSPs (chip size packages) and BGAs (ball grid arrays) are bonded onto the substrate using bumps provided on the bottom face of electronic components. The normal appearance inspection method involves observing the upper face of the substrate, and thus is not effective for inspecting the mounting state of these types of components because the soldered portion is concealed by the electronic component itself after being mounted. Accordingly, the printing state of solder paste (hereafter referred to as "solder") on the substrate is inspected, instead of the appearance inspection, to ensure reliability.

In order to improve the reliability of the inspection itself, all printed points on the substrate should ideally be inspected in the above inspection of the printing

state. However, inspection of all printed points would require a long time because the camera would need to move to each target portion to check and evaluate the printing state by visual recognition. This reduces productivity, and increases equipment costs, since an exclusive inspection apparatus would be needed.

SUMMARY OF THE INVENTION

The present invention aims to provide a method for inspecting the solder printing state at low cost while securing the necessary degree of accuracy.

The inspection method of the present invention is to inspect materials printed in a predetermined pattern on a substrate by detecting the printed state with a detection means.

In the present invention, a test printing portion having the pattern dimension smaller than a minimum printing pattern dimension of actual pattern to be printed is provided on the substrate. After printing, the test printing portion is detected by the detection means for examining the printing state. According to the inspection results of the test printing portion, the printing state of the entire substrate is judged. The test printing portion is provided on a periphery of the substrate out of the effective printing region, or a space region inside the effective printing region. The detector detects the printing state of the test printing portion, and the printing state of the entire substrate is judged based on the inspection results. Accordingly, the present invention enables to inspect the printing state at low cost while securing the necessary degree of accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic side view of a screen printing apparatus in accordance with a preferred embodiment of the present invention.

Fig. 2 is a plan view of the screen printing apparatus in accordance with the preferred embodiment of the present invention.

Fig. 3A is a plan view of a substrate in accordance with the preferred embodiment of the present invention.

Fig. 3B is a plan view of a screen mask of the substrate in accordance with the preferred embodiment of the present invention.

Fig. 4 is a block diagram illustrating the configuration of a control system of the screen printing apparatus in accordance with the preferred embodiment of the present invention.

Fig. 5A illustrates a test printing portion in screen printing in accordance with the preferred embodiment of the present invention.

Fig. 5B illustrates the test printing portion in screen printing in accordance with the preferred embodiment of the present invention.

Fig. 5C illustrates the test printing portion in screen printing in accordance with the preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention is described next with reference to drawings.

First, the configuration of a screen printing apparatus is described with reference to Figs. 1 and 2. In Fig. 1, a substrate positioning unit 1 comprises a transfer table consists of an X-axis table 2 and Y-axis table 3, a theta-axis table 4 piled on the transfer table, and a Z-axis table 5 disposed on the theta-axis table 4. A substrate support 7 is disposed on the Z-axis table 5 for holding the substrate 6 with a clamper 8. A substrate 6 for printing is loaded to the substrate positioning unit 1 by a loading conveyor 14 shown in Fig. 2. The position of the substrate 6 is adjustable by driving the substrate positioning unit 1. After printing, the substrate 6 is unloaded by an unloading conveyor 15.

A screen mask 10 is disposed over the positioning unit 1. The screen mask 10 comprises a frame 11 and screen 12. The substrate positioning unit 1 positions the substrate 6 against the screen 12 in a way that the substrate 6 contacts the screen 12 from the bottom. A squeegee unit 13 is disposed over the screen mask 10 in the horizontally reciprocatable fashion. Solder paste is supplied on the screen 12 when the bottom face of the screen 12 contacts the substrate 5. The squeegee unit 13 slides a squeegee on the surface of the screen 12 for printing solder on the surface of the substrate 6 through an opening 12A (Fig. 2) on the screen 12.

A camera 20 is disposed over the screen mask 10. As shown in Fig. 2, the camera 20 moves horizontally in the XY direction according to the X-axis table 21 and Y-axis table 22. The camera 20 takes the images of a recognition mark provided on the substrate as identification marks and the test printing portion set on the substrate 6. Details of the test printing portion are described later.

As shown in Fig. 2, recognition marks 6a and 6b, which are identification points on the substrate 6, are disposed at diagonal positions. Openings 12A and 12B corresponding to positions of the recognition marks 6a and 6b are created on the

screen 12. In Fig. 2, the recognition mark 6b is located under the screen 12, and thus it is indicated with a broken line. If the substrate 6 is positioned correctly against the screen 12, the recognition marks 6a and 6b are visually recognizable through the openings 12A and 12B, and accordingly their images can be recorded by the camera 20. The position of the substrate 6 is thus detected by checking the recognition marks 6a and 6b. The correction amount of the position of the substrate needed to mount electronic components is then calculated based on the results of detecting the positions of these recognition marks 6a and 6b.

Next, a screen mask for printing the test printing portion and patterns on the substrate 6 is described with reference to Figs. 3A and 3B.

As shown in Fig. 3A, the area inside the edge with a predetermined width of the substrate 6 is a printing pattern area 100 in which solder paste for mounting electronic components is printed. Lands 6c with a range of sizes are formed inside the printing pattern area 100. Solder paste is printed on these lands 6c by screen printing. A test printing pattern 6d for inspecting the printing state is provided on the periphery outside the printing pattern area 100 of the substrate 6.

Fig. 3B shows the screen 12 used for printing the substrate 6. An area 200, indicated with a one-dot chain line, corresponds to the substrate 6. Openings 12a corresponding to the screen pattern of lands 6c on the substrate 6 are created on the screen 12. The test printing pattern opening 12d corresponding to the test printing point 6d is provided at an area corresponding to the periphery of the substrate 6 outside the printing pattern area. The shape of the test printing pattern opening 12d is typically round or rectangular, depending on the land shape in the printing pattern of the target substrate.

The size of the test printing pattern opening 12d is smaller than the size of the solder printing pattern to be printed on the smallest land 6c (m) inside the printing pattern area 100. At present, the minimum size of the solder printing pattern practically used is approximately 0.4 mm. In this case, the size of the test printing pattern 12d is, for example, set to about 0.38 mm. The size of the test printing pattern 12d may be reduced as the size of the printing pattern shrinks further.

Next, the configuration of the control system for the screen printing apparatus is described with reference to Fig. 4. In Fig. 4, the CPU 30 is a control unit which controls all other units described below. A recognition mark position memory 31 stores the positions of the recognition marks 6a and 6b on the substrate 6, openings 12A and 12B created on the screen 12, and the test printing portion. A recognition parameter memory 33 stores data such as the size of the recognition marks and test printing portion. A print position data memory 32 stores the required position correction amount for correcting the position of the substrate 6 with respect to the screen 12 during printing and the position deviation of the test printing portion after printing. The required position correction amount and position deviation are obtained by identifying the recognition marks 6a and 6n, openings 12A and 12B, and test printing portion; and calculating the deviation in the position between the substrate 6 and screen 12.

The camera 20 captures images of the substrate 6 and screen 12, and the image recognizing unit 34 processes the image data obtained by the camera 20 regarding the positions of the recognition marks 6a and 6b and openings 12A and 12B. At the same time, the shape of the solder paste printed on the test printing portion is detected. A judgement unit 36 judges the printing state of the entire substrate based on the printing state of the test printing portion.

The judgement unit 36 first reads out the position data on the test printing portion stored in the recognition mark position memory 31, and recognition parameters for the shape and size of the test printing portion stored in the recognition parameter memory 33. Next, the judgement unit 36 compares the recognition result of a captured image of the test printing portion with the stored data for determining the acceptability of the printed state. The judgement is made by the position deviation of the test printing portion or printing state (the distribution of the printing area detected by optical recognition).

Judgment is made in accordance with the evaluation criteria given in Fig. 5. More specifically, the items to be inspected are " positional deviations " as shown in Fig. 5A, which are deviations in the position of the printed solder from the predetermined printing area " a " ; "unclear" shown in Fig. 5B, which shows insufficient amount of printed solder paste " s " compared to the predetermined amount (which is substituted by the printing area) in the predetermined printing area " a "; and "blur" shown in Fig. 5C which shows excess amount of solder " s " bulging out of the predetermined printing area " a ", as distinct from "unclear." If one of the above items is out of the acceptable criteria, the judgement unit 36 determines that there is some kind of abnormality in the printing state.

A screen printing apparatus in the preferred embodiment of the present invention is configured as described above, and operation of the screen printing apparatus is described below.

After positioning the loaded substrate 6, solder is screen printed onto the substrate 6. The camera 20 is then moved over the substrate 6, and an image of the test printing patternt 6d is captured. The image data are recognized by the image recognition unit 34. Based on the recognition result, the image recognition unit 34

detects the printing state of the solder paste printed on the test printing portion. This detection result is judged by the judgement unit 36. If the judgement unit 36 judges that any one of the aforementioned items is not acceptable, an abnormality in the printing state is announced outside. Based on this notice, printing conditions are changed automatically or manually by the operator as required. If all items are acceptable, the judgement unit 36 judges that screen printing has been properly operated for the entire area on the inspected substrate.

The appropriateness of judging the printing state of the entire substrate based on inspection results of the test printing portion provided on just a portion of the substrate is based on the empirical knowledge of the inventors concerning solder printing quality. In general, the printing of highly viscous paste such as solder paste tends to cause a greater number of defects, such as "unclear" and "blur" as the size of the printing pattern reduces. Accordingly, if correct printing of the minimum printing pattern is confirmed, other printing patterns can be estimated to be satisfactorily printed. In addition, the central part of the screen mask is more likely to achieve a satisfactory printing state during screen printing, and the printing pattern close to the edge of the screen mask tends to cause defective printing.

Accordingly, the test printing portion smaller than the smallest printing pattern in the printing pattern area of the substrate is provided at a portion which is equivalent to the periphery of the screen mask, such as the outer periphery area of the substrate outside the printed pattern area. If this test printing portion is correctly printed, it can be assumed that other printing portions on lands in the printing pattern area are satisfactorily printed.

The preferred embodiment is based on the above empirical knowledge. In other words, a simple inspection means of a camera for detecting the substrate

position and image processing function in the screen printing apparatus are used for inspecting solder printing on the test printing portion on the periphery of the screen mask. This makes it possible to inspect solder printing with appropriate inspection accuracy without requiring an expensive and specially designed high-performance inspection apparatus, which would otherwise be required for inspecting the printing state of the entire substrate.

The above embodiment describes an example of providing the test printing pattern on the outer periphery of the substrate outside the printing pattern area 100. However, the test printing pattern of the present invention is not limited to these positions. For example, the test printing portion may be provided at an area where no land onto which solder paste is printed is present inside the printing pattern area 100, or at the unprinted area near the edge but inside the printing pattern area. The preferred embodiment also employs a camera for detecting the printing state. It is apparent that other instruments, such as a 3-D profilometer, may be used for inspection. Some of other detection means include the well known detection means using transmitted light or X-rays. These disclosed detection means may also be used.

As described above, the present invention provides a test printing portion smaller than the smallest printing pattern, and inspects the printing state by capturing an image of the test printing portion with the detection means. The printing state of the entire substrate is judged in accordance with the inspection results of the test printing portion. The test printing portion is provided in an area at high risk of showing defects, and printed under conditions creating a high risk of causing defects (e.g. reduced printing size).

Inspection of only the test printing portion on behalf of the printing state of the entire substrate to be inspected, without inspecting all printed points enables to secure necessary accuracy, and allow solder printing inspection using a simple and inexpensive method.

The above embodiment describes the case of screen printing. However, the basic concept of the present invention, which is to provide a test point in an area most likely to show a defect under conditions most likely to cause a defect, and to inspect the test point instead of inspecting all points, is applicable to printing methods other than screen printing. Other printing methods include intaglio printing, relief printing, offset printing, and transcription printing.

The present invention is also applicable to the application of adhesives or solder to many points for fixing components to a substrate, typically using a dispenser. One example is to apply test adhesive using a nozzle with a smaller diameter than that of the dispenser nozzle. Ordinary skilled persons in the industry may apply the basic concept of the present invention in a wide range of other ways.

The inspection method of the present invention is not limited to the inspection of circuit substrates, but is also applicable to the manufacturing process of other products which involve a printing process.

What is claimed is:

1. A method for inspecting a printing state comprising:

printing using a mask having i) a required portion, and ii) a test portion, said test portion being provided in an area at a high risk of causing a defect in a condition which has a high risk of causing a defect; and

judging the printing state of an entire printed material by inspecting printing state of said test portion.

2. The method for inspecting a printing state as defined in Claim 1, wherein a substrate to be printed is a circuit board.

3. The method for inspecting a printing state as defined in Claim 2, wherein said method is for inspecting solder paste printed on said circuit board.

4. A method for inspecting a circuit board comprising:

printing a printing material on a circuit board using a mask having i) a required portion, and ii) a test printing portion, said test printing portion having a smaller pattern dimension than a smallest pattern dimension in said required portion;

inspecting a printing state of said test printing portion; and

judging the printing state of an entire circuit board based on a result of said inspection.

5. The method for inspecting a circuit board as defined in Claims 4, wherein said inspection uses one of an optical detection means and X ray.

6. The method for inspecting a circuit board as defined in Claim 4, wherein said printing material is solder paste.

7. The method for inspecting a circuit board as defined Claims 6 wherein said inspection uses one of an optical detection means and X ray.

8. The method for inspecting a circuit board as defined in Claim 6, wherein said judgment of printing state is made based on one of "positional deviation," "unclear," and "blur" of said printing material printed on said circuit board.

9. The method for inspecting a circuit board as defined in Claim 7, wherein said judgment of printing state is made based on one of "positional deviation," "unclear," and "blur" of said printing material printed on said circuit board.

10. The method for inspecting a circuit board as defined in Claim 4, wherein said test printing portion is created at an area outside said required portion.

11. The method for inspecting a circuit board as defined in Claim 6, wherein said test printing portion is created at an area outside said required portion.

12. The method for inspecting a circuit board as defined in Claim 4, further comprising the step of notifying abnormality by judging means when said printing state is judged to be "defective."

13. The method for inspecting a circuit board as defined in Claim 6, further comprising the step of notifying abnormality by judging means when said printing state is judged to be "defective."

14. The method for inspecting a circuit board as defined in Claim 4, further comprising the step of changing a printing condition based on said judgement of a printing state.

15. The method for inspecting a circuit board as defined in Claim 6, further comprising the step of changing a printing condition based on said judgement of a printing state.

16. A substrate having a test printing portion other than a required printing portion on the substrate, said test printing portion having a pattern dimension smaller than a smallest pattern dimension formed on said required printing portion.

17. The substrate as defined in Claim 16, wherein a material printed on said substrate is solder paste.

18. The substrate as defined in Claim 17, wherein said test printing portion is formed on an periphery outside an area where said required solder paste is printed.

19. The substrate as defined in Claim 17, wherein said test printing portion is printed on an unprinted space inside an area where said required solder paste is printed.

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ABSTRACT OF THE DISCLOSURE

A tests printing portion with a pattern dimension smaller than a minimum printing pattern dimension is formed on a substrate, and a printing state of this test printing portion is inspected after printing. Based on inspection results of the test printing portion, acceptability of the printing state of the entire substrate is judged. The test printing portion is created on an periphery of the substrate outside the printing pattern area or an unprinted space inside the printing pattern area. A detection means detects the test printing portion, and inspects its printing state. Based on the inspection results, the acceptability of the printing state of the entire substrate is judged. This enables to inspect the printing state easily at low cost while securing a necessary degree of accuracy.

FIG. 1

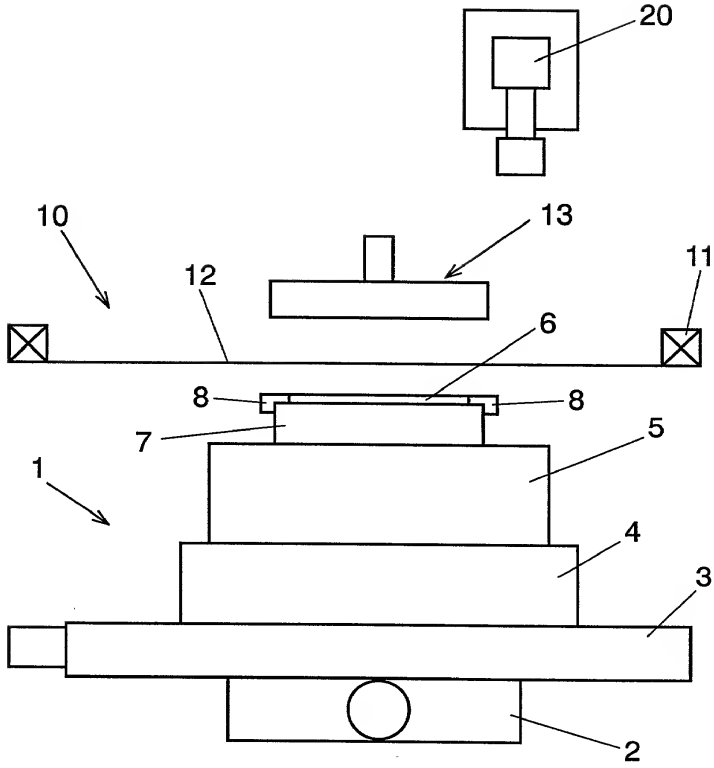


FIG. 2

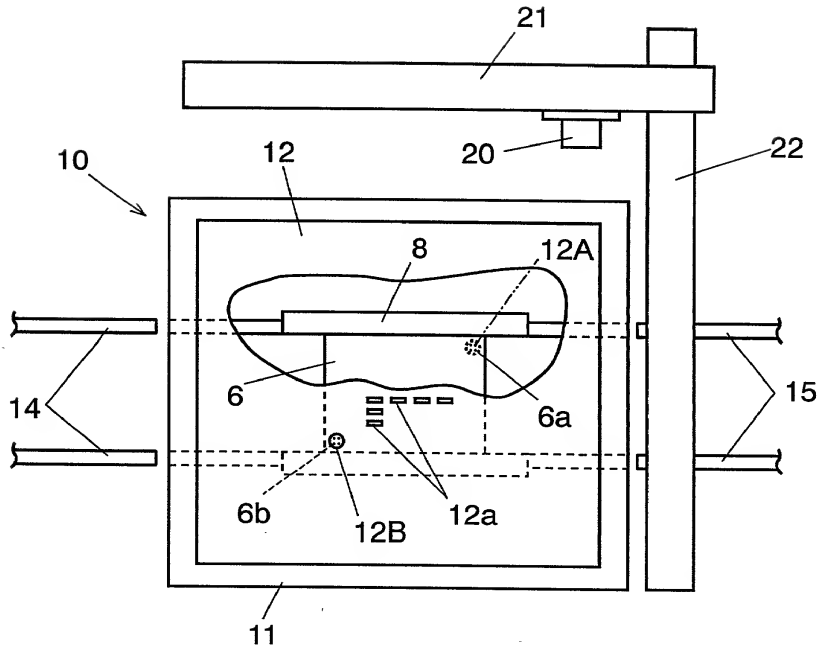


FIG. 3 A

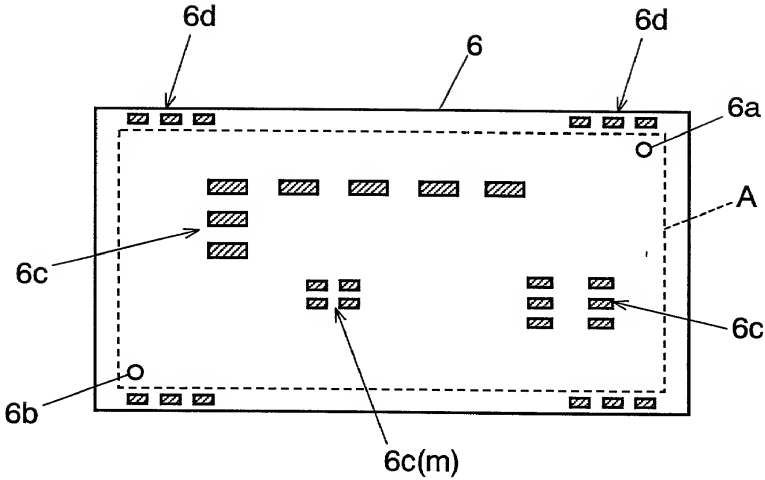


FIG. 3B

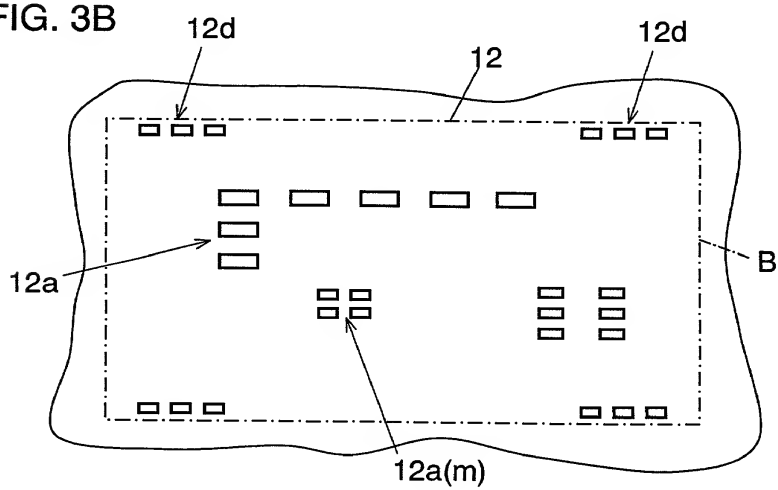


FIG. 4

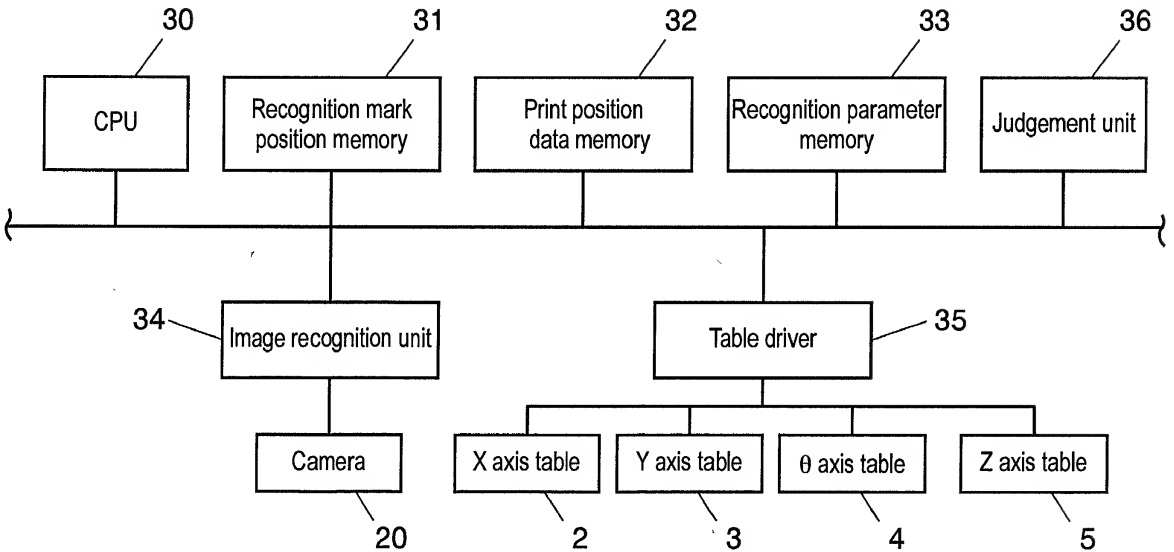


FIG. 5A

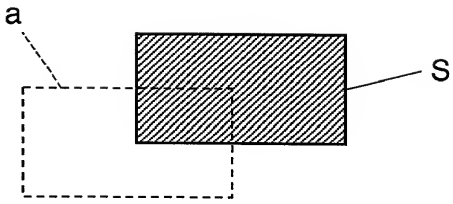


FIG. 5B

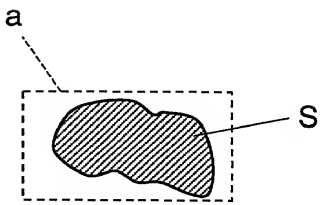
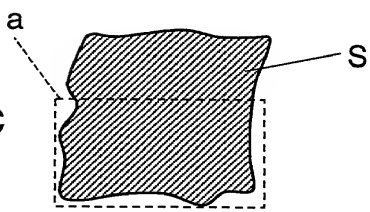


FIG. 5C



DECLARATION AND POWER OF ATTORNEY FOR U.S. PATENT APPLICATION

(X) Original () Supplemental () Substitute () PCT () DESIGN

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Title: METHOD FOR INSPECTING PRINTING STATE AND SUBSTRATE

of which is described and claimed in:
() the attached specification, or
(X) the specification in application Serial No. _____, filed May 23, 2000, and with amendments through _____ (if applicable), or
() the specification in International Application No. _____, filed _____, and as amended on _____ (if applicable).

I hereby state that I have reviewed and understand the content of the above-identified specification, including the claims, as amended by any amendment(s) referred to above.

I acknowledge my duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim priority benefits under Title 35, United States Code, §119 (and §172 if this application is for a Design) of any application(s) for patent or inventor's certificate listed below and have also identified below any application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

COUNTRY	APPLICATION NO.	DATE OF FILING	PRIORITY CLAIMED
Japan	11-142871	May 24, 1999	YES

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION SERIAL NO.	U.S. FILING DATE	STATUS: PATENTED, PENDING, ABANDONED

And I hereby appoint Michael R. Davis, Reg. No. 25,134; Matthew M. Jacob, Reg. No. 25,154; Jeffrey Nolton, Reg. No. 25,408; Warren M. Cheek, Jr., Reg. No. 33,367; Nils Pedersen, Reg. No. 33,145; and Charles R. Watts, Reg. No. 33,142, who together constitute the firm of WENDEROTH, LIND & PONACK, L.L.P., jointly and severally, attorneys to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith.

I hereby authorize the U.S. attorneys named herein to accept and follow instructions from Matsushita Electric Industrial Co., Ltd. as to any action to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and myself. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys named herein will be so notified by me.

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Residence & Citizenship	CITY	STATE OR COUNTRY	COUNTRY OF CITIZENSHIP
Post Office Address	ADDRESS	CITY	STATE OR COUNTRY ZIP CODE
Full Name of Sixth Inventor	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
Residence & Citizenship	CITY	STATE OR COUNTRY	COUNTRY OF CITIZENSHIP
Post Office Address	ADDRESS	CITY	STATE OR COUNTRY ZIP CODE

I further declare that all statements made herein of my own knowledge are true, and that all statements on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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Takaaki SAKAUE

4th Inventor _____ Date _____

5th Inventor _____ Date _____

6th Inventor _____ Date _____

The above application may be more particularly identified as follows:

U.S. Application Serial No. _____ Filing Date May 23, 2000

Applicant Reference Number P22824-01(I.S.Hasegawa) Atty Docket No. 2000_0619A

Title of Invention METHOD FOR INSPECTING PRINTING STATE AND SUBSTRATE